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SOFTWARE SUPPORT TO ENVIRONMENTALY FRIENDLY PRODUCT DESIGN – CLASSIFICATION AND FEASIBILITY STUDY

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Abstract. *It is expected that environment - oriented expert and decision support systems, material and process databases, and eco-design support software would become standard engineering tools in nearest future. Of particular importance for environmental impact assessment of a product is the availability of software tools to accept the data and process it in a manner that is consistent with the users' intended purpose and goals. Already now there are several software packages and databases that cover one or more segments of eder Design for Environment (DFE) which gained general acceptance as approach in designing industrial products, or Life Cycle Assessment (LCA) – widely accepted method that cover a range of uses (eco-design, product environmental improvement, and environmental impact evaluation). After an initial screening of software tools selected for the purpose, this paper aims to raise awareness of these relatively less known kind of software among potential users / developers and to indicate needs for further software development in this field of growing significance.*

Key words: *environmental product design, software tools, design for environment*

1. INTRODUCTION

The concept of Sustainable Development presupposes that the needs of humanity could be satisfied without further deterioration of natural resources and values. To achieve this ambitious goal, new design strategies should lead toward environmentally benign products and manufacturing, i.e. "front-end" environmental protection. The concept of Design for Environment (DFE) is one such strategy aimed to meet present requirements. As a result of its implementation, an environmentally friendly product should be conceived. It should perform minimum impact on environment in phases of

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manufacturing, use, and disposal / recycling. A Life Cycle Assessment (LCA) is necessary to obtain a comprehensive overview on entire product's environmental impact. Life-cycle assessment (LCA) is a process to evaluate the resource consumption and environmental burdens associated with a product, process, package, or activity. The LCA process encompasses the identification and quantification of energy and material usage, as well as environmental releases across all stages of the life cycle; the assessment of the impact of these energy and material uses and releases to the environment; and the evaluation and implementation of opportunities to effect environmental improvement [3].

DFE has gained general acceptance as approach in designing industrial products in last decade, and LCA as a tool with a range of uses, such as product environmental improvement, eco-design, and environmental impact evaluation. While the acceptance of DFE and LCA has expanded, the development of software tools for assisting design process and performing LCA has increased. Many of these software tools and databases are available today as indispensable tools to support designers in their efforts to act in environmentaly friendly manner.

2. FEASIBILITY

Of particular importance for environmental impact assessment of a product is the availability of software tools that can accept the data and process it in a manner that is consistent with the users' intended purpose and goals. Designers usually require quick and easily operable tool to assist entire design process, environmental managers in production plants would be primarily interested in waste minimisation software tools, while product stewards should require comprehensive information on entire product-environment interaction across all stages of the life cycle.

It is expected environment oriented expert and decision support systems, material and process databases and eco-design support software to become a standard engineering tools. Already now there are several software packages and databases that cover one or more segments of DFE. In unpublished report titled "Evaluation of Life Cycle Assessment Tools" by Hazardous Waste Branch, Environment Canada, 37 software tools in different stages of development were identified, whereof 14 were obtainable and preliminary evaluated. Upon initial evaluation, five tools were selected for an in – depth evaluation. Findings of this study are shown in tables 1 and 2 [2].

Table 1. Selection Criteria and Corresponding Software Tools by Env. Can.

Criteria	**Software Tools**
highly detailed and representative life-cycle inventory	KCL-ECO and TEAM
impact assessment capabilities and flexibility	LCAiT and PEMS
extent of use within industry	SimaPro

Situation has changed since, and author of this study identified more than 45 software titles that deal with the issue in case. The only tool among chosen ones that appears both in above mentioned report and this study is SimaPro (PRE Consultants), but this time in improved release 4. This obviously comprehensive approach could become future industrial standard of the kind.

Table 2. Comparison of Software Features by Env. Can.

	KCL-ECO	LCAiT	PEMS	SimaPro	TEAM™
Graphical Interface	✓	✓	✓		✓
Unit Flexibility	✓			✓	✓
Use of Formulas	✓				✓
Uncertainty Analysis	✓		✓		✓
Impact Assessment		✓	✓	✓	✓
Comparison of Results			✓	✓	✓
Graphical Display of Results		✓	✓	✓	

3. CLASSIFICATION

To develop a complex product taking in consideration its interaction with the environment, combination of concerns is required, such as: inventory of inputs and outputs, strategic planning, selection of technological procedures, disposal logistics, matching legislative requirements and analysis of economical feasibility on proposed solutions. Such a broad field of activities certainly isn't always possible to divide on segments, especially not in terms of software applications that should facilitate and improve design solutions. However, contours of particular activities are recognisable, and allow for general classification of software tools according to their role in conceiving new development strategies:

- software tools for waste minimisation, structure optimisation and virtual prototyping
- software tools and databases for LCA, material and energy inventory and impact assessment
- software tools for structural, technical - financial feasibility analysis of dismantling procedures, recyclability and disposal.

– The first category encompasses several CAD, FEM and similar packages that are not primarily aimed for solving industrial ecology problems, but readily follow environmental principles. Recently, there are numerous "add – ons", "third party" plug-ins or modules for advanced tools such as ProENGINEER (Parametric Tech. Corp.), MICROSTATION (Bently Systems Inc.), SOLIDWORKS (Solid Works Inc.), etc. that significantly contribute minimizing material consumption by optimizing structures. However there are applications such as PRONEST (MTC, Ltd.) specially designed to optimize material consumption by e.g. automatic nesting with two-axis profile cutting equipment. System accepts most frequently used CAD formats (DWG, DXF, DGN, IGES, EPS). Built-in features include multitorch nesting, cutting sequence optimization, automatic nesting of full sheets, etc.

– SimaPRO (PRE Consultants B.V.) is typical representative of the second category. Since its introduction in 1990, this software has been widely used tool for the environmental assessment of products. It allows implementing LCA in quite flexible manner. A huge amount of data is stored in SimaPro databases including processes, substances, methods and impact assessment databases. Process data are stored in SPOLD (Society for the Promotion of LCA Development) format that becomes LCA data- format standard. Powerful feature is

comparation of two or more different products, and providing reports on those comparation studies. Script language provides a simple user interface for non-experts, while for designers there is user friendly "Eco-it" tool developed to be used with SimaPro.

To analyze or compare products in an LCA, it is necessary to define and quantify the function for which they are used. The so called functional unit provides a reference against which the use of each product is normalized. Thus, any analyses or comparisons are carried out on the basis of the same function, measured by the same functional unit. To adequately define a functional unit, information must be available on how the product is produced, used and disposed of. Similar information is required on its component parts.

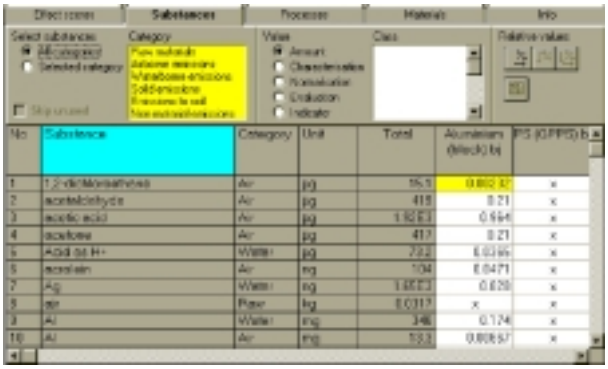

Fig. 1. Inventory table (SimaPro)

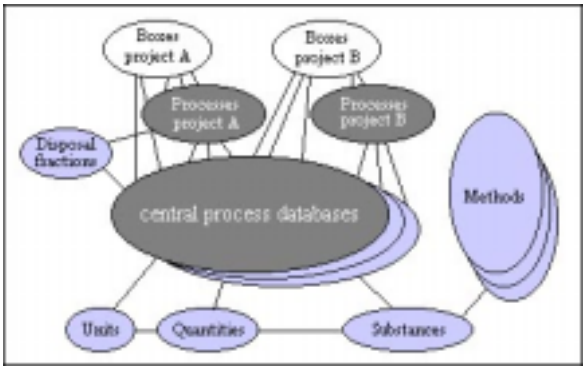

Fig. 2. SimaPro databases

"Eco-it" tool is of particular importance. With ECO-it designers have a tool to really measure and optimize the environmental performance of products in the design phase. It allows designer to describe a complex product and its life cycle just by entering the materials and processes that are used. ECO-it immediately calculates the environmental load, and shows which parts of the product contribute most. Based on this information designer can target his creativity to reduce the environmental load of the product. ECO-it comes with over 100 indicator values for commonly used materials such as metals, plastics, paper, board and glass, as well as production, transport, energy and waste treatment processes [4]. These

indicators are in form of predefined building blocks for modeling a life cycle.

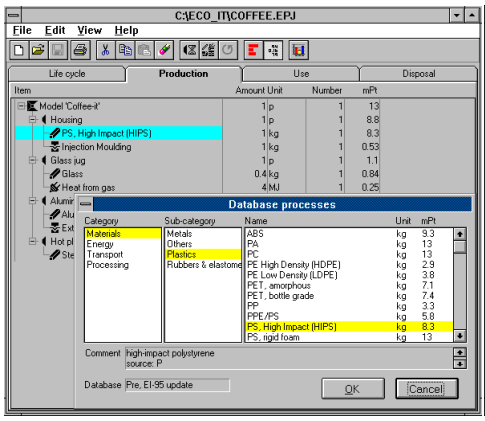

Fig. 3. Process database (Eco It)

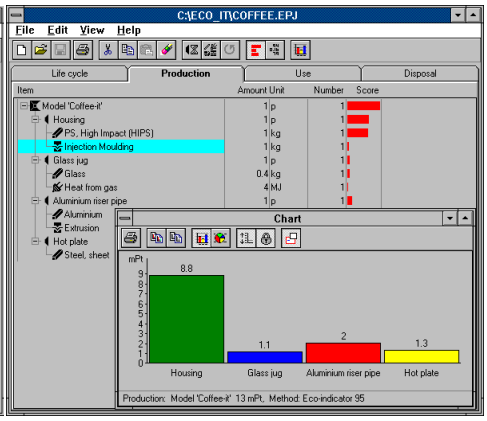

Fig. 4. Production impact assessment

Another illustrative and feature reach tool of the kind is IDEMAT (TU Delft). Idemat is a computer database for designers, developed by the section Environmental Product Development of the faculty of Industrial Design Engineering at the Delft University of Technology. It provides technical information about materials and processes in alphanumerical and graphical format, and puts emphasis on environmental information. Database consists of mechanical, physical, electrical, and other characteristics such as manufacturability, environmental suitability, etc. for 365 technical materials. Impact assessment is disposed using so-called European scale related to one kg of applied material. Program is particularly useful for material selection since it allows preliminary palette of materials according to defined mechanical, or physical criteria. Apart from material, there are sections "Processes" and "Components" that significantly facilitate design procedure.

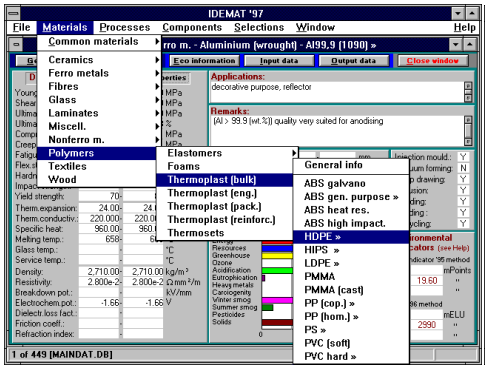

Fig. 5. Material data (IDEMAT)

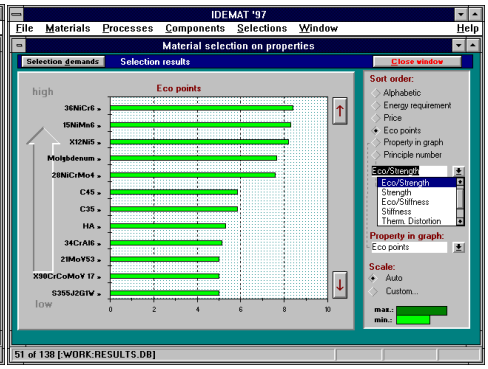

Fig. 6. Environmental assessment

For effective use the user should be familiar with the principles of Life Cycle Assessment and the methods for characterization and evaluation of the environmental

used in Simapro. The program is an application of Borland Paradox and runs independently, without additional programs.

– Among the few in the third category, "Design for Disassembly" (Boothroyd Dewhurst, Inc.) is quite illustrative and comprehensive. Program optimizes disassembly sequence by calculating gain or loses at every stage during dismantling procedure, taking into account disposal costs or recycling profits. Initial disassembly sequence is generated according to user-defined elements and subassemblies. Environmental effects of particular procedures are expressed by so called "MET point rating system". Financial analysis, environmental impact and duration of every dismantling step are displayed at the same graphic.

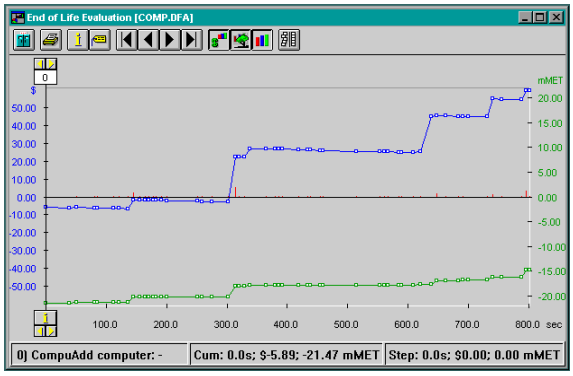

Fig. 7. Financial line and eco points (DFD)

4. CONCLUSION

Many of environment - oriented software tools and databases available today are indispensable tools that significantly support designers in their efforts to act in environmentaly friendly manner. However, certain improvements are both needed and desirable.

One interesting initiative is launched under acronym (L-CAD). The Life-Cycle Computer Aided Data (L-CAD) is project conducted by Battelle's Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE) Industrial Waste Program (IWP). The two fundamental objectives of the L-CAD project are (1) to collect and disseminate energy and environmental data for industrial commodities and (2) to develop a "next generation" computer modeling system. Reaching this ambitious goal could lead to effective software tools suitable for new way of thinking. Table below reveals some general requirements that modern software tools for environmentally friendly product design should meet.

Certain software producers support sustainable design initiatives in superior manner. However, there is a need for ever new, comprehensive and versatile eco – design tools that would support new design strategies. Applying multicriteria optimization models, visualization and user friendliness, would be new marks of quality.

Table 3. The list of general requirements

General	Single and Multi user (network) version Ability to develop Scripts Options for extra databases
Product description and LC	Modeling of complex products and graphical editing option Modeling of disassembly and reuse scenarios Modeling of waste processing scenarios
Inventory of process data	Completely open database edited and expanded by the user Use of the standardized SPOLD format Emission linked to a treatment process Use of separate databases per project
Impact assessment	Full representation of the impact table Multiple evaluation methods Development of new evaluation methods by the user Classification, characterization, normalization, evaluation modes Analysis of impacts of each part or life cycle stage of the product Analysis of effect scores
Other functions	Import/export function for data, methods, projects and databases Full printing of graphs and tables

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SOFTVERSKA PODRŠKA EKOLOŠKI PODOBNOM PROJEKTOVANJU - KLASIFIKACIJA I STUDIJA PRIMENLJIVOSTI

Srdjan Glišović

Očekuje se da u najskorijoj budućnosti sistemi za podršku odlučivanju, baze materijala i procesa, i ostali specijalizovani programski paketi namenjeni projektovanju ekološki podobnih proizvoda postanu nezaobilazni inženjerski alati. Novi pristup projektovanju pod nazivom "Design for Environment" (DFE - projektovanje ekološki podobnih proizvoda) poslednjih godina prihvaćen je kao platforma za formiranje industrijskih proizvoda budućnosti. U isto vreme, metodologija "Life Cycle Assessment" (LCA - "procena životnog ciklusa") dobija na značaju kao nezaobilazan alat u oceni uticaja proizvoda i tehnologija na životnu sredinu u fazama ekstrakcije, produkcije, upotrebe i dispozicije po isteku upotrebne vrednosti. Sa sveopštim prihvatanjem DFE i LCA kao platforme i metodologije, došlo je do ubrzanog razvoja softverskih alata i baza podataka za podršku projektovanju i sprovođenje ekoloških ekspertiza nad proizvodima i procesima. Mnogi

alati ove kategorije su već u ovom trenutku komercijalno dostupni, i pokrivaju jedan ili više segmenata u okviru nastojanja da se u razvojnoj fazi postigne smanjenje opterećenja životne sredine antropogenim uticajima. Predmet ovog rada je pregled i analiza raspoloživih softverskih alata, i ukazivanje na prednosti, nedostatke i pravce daljeg razvoja ove nedovoljno poznate kategorije softvera. Izvršena je klasifikacija, analiza strukture postojećih alata i formirana lista zahteva za potrebe korisnika i projektanata zainteresovanih za razvoj ove aktuelne i dinamične oblasti.

Ključne reči: *ekološko projektovanje, programska podrška projektovanju, analiza životnog ciklusa*